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THE GROWTH-PROMOTING PROPERTIES OF MILK AND DRIED-MILK PREPARATIONS

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THE GROWTH-PROMOTING PROPERTIES OF MILK AND DRIED-MILK PREPARATIONS.[1]

By J. M. JOHNSON, Chemist, Division of Pharmacology, Hygienic Laboratory, United States Public Health Service.

Numerous investigators have studied the effect of milk upon growth. Janet Lane-Claypon [2] found practically no difference between boiled and raw milk when fed with bread to growing albino rats. F. G. Hopkins [3] observed that when rats are fed upon a well-balanced diet of purified foodstuffs, furnishing all the necessary elements except the growth-promoting accessories, which, as shown by control experiments, did not permit normal growth, the addition of very small amounts of fresh milk, from 1 to 3 or 4 per cent of the total solids of the food, gave immediate and good growth.

Osborne and Mendel,[4] however, found that in feeding fresh milk to rats as the sole source of water-soluble vitamine, at least 16 c. c. daily were required to give normal growth, and sometimes even that amount failed.

G. Winfield [5] found that 87 infants fed upon dried whole milk, compared with infants fed upon the breast, did not grow as well as the latter at first, but later made approximately normal or even better growth. Experiments upon 40 rats fed upon dried whole milk only, showed that normal health was maintained for a period of 16 months or more, but growth fell below normal when one-half to two-thirds of adult weight was reached. Osborne and Mendel [6] found that it was necessary to use at least 24 per cent dried whole milk in making up a food mixture which would give normal growth to rats.

The object in the experiments carried out by the author of this paper was to compare raw and pasteurized cow's milk with that obtained by addition of the required amount of water and butter fat to skim milk powder, so-called "reconstructed" milk. This milk has come into use in certain places where there is a scarcity of dairy herds. Under normal conditions it can not be produced more economically than fresh milk; but where transportation for great distances enters into the equation, because of the fact that 87 per cent water must be carried with fresh milk, it pays to consider "reconstructed" milk. Therefore, the question comes up whether

[1] Reprint from the Public Health Reports, vol. 36, No. 34, Aug. 26, 1921, pp. 2044-2057.
[2] Jour. Hyg. (1909), IX, 233.
[3] Jour. Physiol. (1912), XLIV, 425.
[4] Jour. Biol. Chem. (1918), XXXIV, 537.
[5] Brit. Local Govt. Board Food Rep. (1918), XXIV, 139-56.
[6] Loc. cit.

it is safe to allow this milk to be sold where the public will place the same reliance upon it as upon fresh milk as a food for children or adults.

MILKS STUDIED.

1. Reconstructed milk made from skim milk powder by the addition of butter and water. The skim milk powder was obtained from a factory using the spray method of drying. For a good part of the time of the experiment this milk was secured from a restaurant conducted under the auspices of the United States War Department, where the milk powder, water, and butter were mixed in a machine especially devised for this purpose. During the other part of the experiment the milk was made up in the Laboratory so as to approximate the composition of standard pasteurized milk with 3.5 per cent butter fat.

2. Raw milk obtained from the dairy of the United States Department of Agriculture.

3. Raw certified milk obtained from a local dairy.

4. Pasteurized milk obtained from another local dairy.

5. A few experiments were also carried out with a mixture of skim milk powder and a basal diet.

METHOD OF FEEDING.

Healthy young white rats weighing 40 to 60 grams were selected and kept in individual cages. The food intake was accurately controlled. The animals were kept supplied with fresh water. Body weight was taken twice a week. The food was made up as follows: A basal mixture was made of starch, 48 per cent; casein, 25 per cent; Osborne and Mendel's[7] salt mixture, 5 per cent; lard, 10 per cent; unsalted butter, 10 per cent; powdered agar, 2 per cent. The casein in this mixture was washed free of water-soluble vitamine with dilute acetic acid, followed by washing with water many times, and was dried and ground before using. Ten per cent of butter was selected in order to give the animals an excess of fat-soluble vitamine, since the experiments dealt only with a comparison of water-soluble vitamine in the milks. In the making of reconstructed milk, butter is used; therefore a study of its fat-soluble vitamine content was unnecessary.

The diets fed to the rats were made up fresh each day by the addition of measured portions of the milk with a weighed portion of the basal mixture. No control experiments were run upon the basal mixture alone, but proof was obtained that it contained no growth-promoting accessories by the experiments with small amounts of milk mixed with it, when all the animals failed to grow. The animals were given each day slightly more food than they would eat. This caused a moderate variation in the food consumption of rats on the same diet.

[7] Jour. Biol. Chem. (1917), XXXII, 317.

In order to be sure that there was no appreciable difference between the chemical composition of these various milks, chemical analyses were made at frequent intervals during the progress of the experiment. Averages are given for the month in each case. Although the results of the chemical analyses show that there is quite a marked variation of the fat and total solids content, I do not think that the difference is great enough to cause an appreciable change in the concentration of the water-soluble vitamine.

TABLE I.—*Average chemical composition of milks.*[1]

Month.	Total solids.	Fat.	Solids not fat.	Protein.	Ash.	Milk.
1919.						
June	12.48	4.01	8.47	3.16	0.541	Agricultural Department.
Do	13.38	3.73	9.58	3.58	.64	Reconstructed.
July	12.81	4.33	8.48	3.11	.55	Agricultural Department.
Do	13.19	4.09	9.10	3.36	.59	Reconstructed.
August	12.63	4.10	8.53	3.17	.55	Agricultural Department.
Do	12.86	4.12	8.74	3.05	.61	Reconstructed.
September	13.40	4.83	8.57	3.28	.....	Agricultural Department.
Do	12.77	4.07	8.70	3.12	.....	Reconstructed.
October	14.38	5.74	8.63	3.42	.....	Agricultural Department.
Do	11.98	3.72	8.26	2.94	.....	Reconstructed.
November	15.40	6.5	8.65	3.31	.....	Agricultural Department.
Do	12.10	3.65	8.46	3.11	.....	Reconstructed.
December	14.81	5.9	8.30	3.39	.....	Agricultural Department.
Do	12.43	3.68	8.75	3.21	.....	Reconstructed.
1920.						
January	13.86	5.2	8.63	3.38	.....	Agricultural Department.
Do	12.83	3.65	9.18	3.50	.....	Reconstructed.
February	15.26	6.93	8.32	3.26	.....	Agricultural Department.
Do	.....	5.1	.....	.....	.....	Local certified.
Do	.....	4.2	.....	.....	.....	Local pasteurized.
March	15.62	7.48	8.14	3.14	.....	Agricultural Department.
Do	.....	6.0	.....	.....	.....	Local certified.
April	12.73	4.3	8.39	3.12	.....	Agricultural Department.
Do	.....	3.5	.....	.....	.....	Local certified.
May	12.88	4.33	8.55	3.15	.....	Agricultural Department.
Do	.....	4.8	.....	.....	.....	Local certified.
Do	.....	3.1	.....	.....	.....	Local pasteurized.

[1] The chemical analyses of the milks were carried out by various members of the division of chemistry of the Hygienic Laboratory, most of them by Mr. O. H. Schunk and Mr. C. G. Remsburg.

Table II gives the various diets fed.

TABLE II.—*Diets fed.*

Diet No.	Amount of basal mixture.	Amount of milk.	Diet No.	Amount of basal mixture.	Amount of milk.
IV	100	25 Agricultural Department plus 25 water.	V	100	100 reconstructed.
			X	100	200 reconstructed.
III	100	50 Agricultural Department plus 50 water.	XIII	100	250 reconstructed.
			XIV	100	300 reconstructed.
II	100	25 Agricultural Department plus 75 water.	XVI	100	350 reconstructed.
			XXII	100	200 local pasteurized.
I	100	100 Agricultural Department.	XX	100	250 local pasteurized.
VIII	100	150 Agricultural Department.	XVII	100	300 local pasteurized.
IX	100	200 Agricultural Department.	XVIII	100	350 local pasteurized.
XI	100	250 Agricultural Department.	XXI	100	250 local certified.
XII	100	300 Agricultural Department.	XIX	100	300 local certified.
XV	100	350 Agricultural Department.	XXIII	100	31.2 grams spray process skim milk powder.
VII	100	50 reconstructed plus 50 water.			
VI	100	75 reconstructed plus 25 water.			

RESULTS.

Table III gives the results of the experiments carried out with the diets composed of basal mixture plus Agricultural Department raw milk. In some cases where the rat failed to show good growth, small amounts of yeast were given in order to supply additional water-soluble vitamine. This usually caused improvement. This addition of yeast is not shown in the tables, but will be found indicated in the charts at the end of the article.

TABLE III.—*Summary of experiments on rats fed on Agricultural Department milk.*

Number of rat.	Diet fed.	Initial weight.	Maximum weight.	Final weight.	Duration of experiment in days.	Average c. c. of milk consumed daily.		Remarks.
						Number of days weighed.	C. c.	
		Grams.	*Grams.*	*Grams.*				
26♂	IV	66	125	104	149	All.	1.5	Discharged.
27♀	IV	63	135	130	149	All.	1.5	Do.
28♂	IV	43	108	69	137	All	1.1	Died.
29♀	IV	61	113	109	149	All.	1.4	Discharged.
32♀	IV	47	100	82	149	All.	1.1	Do.
33♂	IV	54	137	123	149	All.	1.5	Do.
17♂	III	63	80	78	39	All.	2.7	Changed to IX.
17♂	IX	78	153	142	104	All.	10.8	Discharged.
23♀	III	50	71	71	39	All.	2.8	Changed to IX.
23♀	IX	71	129	124	104	All.	9.7	Discharged.
24♀	III	64	71	68	39	All.	2.6	Changed to IX.
24♀	IX	68	136	121	104	All.	9.2	Discharged.
9♀	II	53	100	86	133	All.	3.9	Do.
11♂	II	73	180	178	149	All.	5.8	Do.
12♀	II	42	110	104	133	All.	3.9	Do.
13♂	II	80	244	226	149	All.	6.1	Do.
14♀	II	57	97	91	133	All.	3.3	Do.
15♀	II	64	142	141	133	All.	4.3	Do.
16♀	II	56	103	101	133	All.	3.4	Do.
1♀	I	47	58	58	39	All.	4.5	Changed to VIII.
1♀	VIII	58	60	43	68	All.	4.3	Died.
3♂	I	55	77	74	39	All.	4.7	Changed to VIII.
3♂	VIII	74	140	135	104	All.	8.6	Discharged.
4♀	I	62	94	94	39	All.	6.2	Changed to XIII.
4♀	VIII	94	140	140	94	All.	9.3	Discharged.
5♂	I	58	119	119	39	All.	7.0	Changed to VIII.
5♂	VIII	119	182	166	104	All.	10.9	Discharged.
7♂	I	62	117	115	39	All	7.9	Changed to VIII.
7♂	VIII	115	195	187	104	All.	9.7	Discharged.
8♀	I	67	95	88	39	All.	5.9	Changed to VIII.
8♀	VIII	88	110	100	94	All.	6.1	Discharged.
102♂	IX	88	210	205	157	45	13.0	Died.
103♀	IX	78	150	150	189	49	11.4	Discharged.
104♀	IX	75	188	188	180	48	14.5	Do.
84♂	XI	47	220	202	198	62	17.4	Do.
85♂	XI	49	284	284	198	64	20.0	Do.
86♀	XI	44	224	203	198	61	18.1	Do.
87♂	XI	47	286	286	198	61	21.5	Do.
88♀	XI	43	211	211	198	61	16.0	Do.
53♀	XII	46	165	158	209	35	17.7	Do.
54♂	XII	62	295	295	209	39	22.9	Do.
55♂	XII	58	270	270	209	35	23.1	Do.
56♀	XII	56	182	182	209	35	19.9	Do.
57♂	XV	77	237	232	253	64	22.5	Do.
58♀	XV	53	200	200	209	35	24.2	Do.
59♀	XV	52	203	203	209	35	21.5	Do.
77♀	XV	46	187	180	212	53	15.9	Accident; died.

It is seen from Table III that a food mixture consisting of purified foodstuffs plus milk as the sole source of water-soluble vitamine must contain at least 2½ parts of milk to 1 part of the basal ration in

order to produce normal growth. Since a full-grown male rat weighs about 280–300 grams, and a full-grown female about 180 grams, a rat upon such a diet consumes just about 16–18 cubic centimeters of milk daily. These figures agree with those of Osborne and Mendel.[8] It is also seen that the rate of growth of rats receiving less than 2½ parts of milk in their diet was accelerated after increasing the amount of milk in the diet.

The results obtained with reconstructed milk (Table IV) show that here again normal growth was not attained until the milk mixture was composed of at least 2½ parts of milk to 1 part of basal ration.

TABLE IV.—*Summary of experiments on rats fed on reconstructed milk.*

Number of rat.	Diet fed.	Initial weight.	Maximum weight.	Final weight.	Duration of experiment in days.	Average c. c. of milk consumed daily.		Remarks.
						Number of days weighed.	C. c.	
		Grams.	*Grams.*	*Grams.*				
44♀	VII	39	87	81	116	All.	1.8	Discharged.
45♀	VII	35	95	92	116	All.	1.9	Do.
47♀	VII	48	100	87	116	All.	2.2	Do.
48♂	VII	30	139	139	131	All.	2.4	Do.
39♀	VI	33	71	67	116	All.	2.8	Do.
40♀	VI	51	100	100	116	All.	3.6	Do.
41♀	VI	34	101	52	106	All.	3.1	Died.
42♂	VI	48	149	135	126	All.	4.5	Discharged.
43♀	VI	48	104	94	116	All.	3.3	Do.
35♂	V	62	145	130	116	All.	6.4	Do.
36♀	V	30	91	62	101	All.	3.9	Died.
37♂	V	39	100	97	116	All.	4.0	Discharged.
49♀	X	38	157	157	342	All.	11.4	Do.
50♀	X	49	168	152	320	All.	9.1	Do.
51♀	X	44	154	149	240	All.	10.7	Do.
52♀	X	75	230	230	246	All.	13.4	Do.
115♀	X	41	72	50	40	21	7.6	Died.
89♀	XIII	55	197	192	198	58	14.8	Discharged.
90♀	XIII	54	205	200	198	53	16.1	Do.
91♀	XIII	40	187	187	198	57	14.2	Do.
92♀	XIII	45	168	165	198	50	12.2	Do.
61♂	XIV	58	297	297	209	32	22.6	Do.
62♂	XIV	62	254	252	266	64	15.1	Do.
113♂	XIV	47	232	164	116	94	17.9	Do.
63♀	XVI	45	182	182	209	31	18.1	Do.
64♂	XVI	64	281	281	208	30	25.7	Do.
65♀	XVI	46	195	194	208	29	19.1	Do.
66♂	XVI	40	216	216	208	28	24.0	Do

[8] Loc. cit.

The results on pasteurized milk (Table V) again show that not until the food mixture is composed of at least $2\frac{1}{2}$ parts of milk to 1 part of basal ration is there normal growth obtained.

TABLE V.—*Summary of experiments on rats fed on pasteurized milk.*

Number of rat.	Diet fed.	Initial weight.	Maximum weight.	Final weight.	Duration of experiment in days.	Average c. c. of milk consumed daily.		Remarks.
						Number of days weighed.	C. c.	
		Grams.	*Grams.*	*Grams.*				
105 ♀	XXII	38	154	152	180	57	11.6	Discharged.
107 ♀	XXII	59	160	151	163	59	10.9	Do.
108 ♂	XXII	45	127	99	73	8	7.1	Died.
114 ♀	XXII	40	162	160	126	86	16.2	Discharged.
94 ♂	XX	40	275	275	198	70	21.3	Do.
95 ♂	XX	45	227	227	198	67	19.2	Do.
96 ♂	XX	60	227	227	198	67	16.3	Do.
67 ♀	XVII	41	213	213	208	29	21.1	Do.
69 ♀	XVII	32	207	207	208	39	19.3	Do.
101 ♂	XVII	55	260	260	198	74	20.6	Do.
70 ♂	XVII	43	305	302	208	36	19.3	Do.
71 ♂	XVIII	45	240	240	208	37	26.6	Do.
72 ♀	XVIII	45	193	187	208	36	21.4	Do.
73 ♀	XVIII	50	221	221	208	36	22.6	Do.
74 ♀	XVIII	47	203	203	89	(1)	.....	Unknown.
106 ♀	XVIII	76	185	184	175	77	23.9	Discharged.

[1] Accident; died.

The results on certified milk (Table VI) are in accord with those found in the other milks; that is, that it is necessary to use $2\frac{1}{2}$ parts of milk to 1 part of basal mixture to give a ration that will produce full growth in rats.

TABLE VI.—*Summary of experiments on rats fed on local certified milk.*

Number of rat.	Diet fed.	Initial weight.	Maximum weight.	Final weight.	Duration of experiment in days.	Average c. c. of milk consumed daily.		Remarks.
						Number of days weighed.	C. c.	
		Grams.	*Grams.*	*Grams.*				
97 ♀	XXI	52	190	190	198	71	15.5	Discharged.
98 ♀	XXI	44	187	187	198	66	16.7	Do.
99 ♀	XXI	54	207	205	198	63	18.6	Do.
100 ♂	XXI	67	297	294	178	66	19.4	Do.
117 ♂	XXI	47	315	315	70	66	27.4	Do.
118 ♂	XXI	36	285	285	70	66	25.8	Do.
119 ♂	XXI	40	270	270	91	66	23.0	Do.
120 ♀	XXI	38	180	180	98	66	20.2	Do.
121 ♀	XXI	42	185	185	70	66	19.8	Do.
122 ♂	XXI	43	235	230	98	66	21.4	Do.
123 ♀	XXI	45	189	185	91	66	19.3	Do.
79 ♀	XIX	37	195	184	216	74	18.2	Do.
80 ♀	XIX	50	197	188	203	64	22.4	Do.
81 ♂	XIX	42	260	258	216	75	21.7	Do.
82 ♀	XIX	54	247	214	235	65	18.6	Do.
83 ♀	XIX	59	185	170	216	75	15.2	Do.

Table VII gives the results obtained on feeding a dry mixture of the basal ration plus skim milk powder.

TABLE VII.—*Summary of experiments on rats fed on spray process skim-milk powder plus basal mixture.*

Number of rat.	Diet fed.	Initial weight.	Maximum weight.	Final weight.	Duration of experiment in days.	Average grams of milk powder consumed daily.		Remarks.
						Days weighed.	Grams.	
		Grams.	*Grams.*	*Grams.*				
109♂	XXIII.....	46	280	270	165	97	2.6	Discharged.
110♂	XXIII.....	45	240	234	150	94	2.4	Do.
111♂	XXIII.....	54	204	190	165	99	2.5	Do.
112♀	XXIII.....	53	185	178	153	97	2.5	Do.

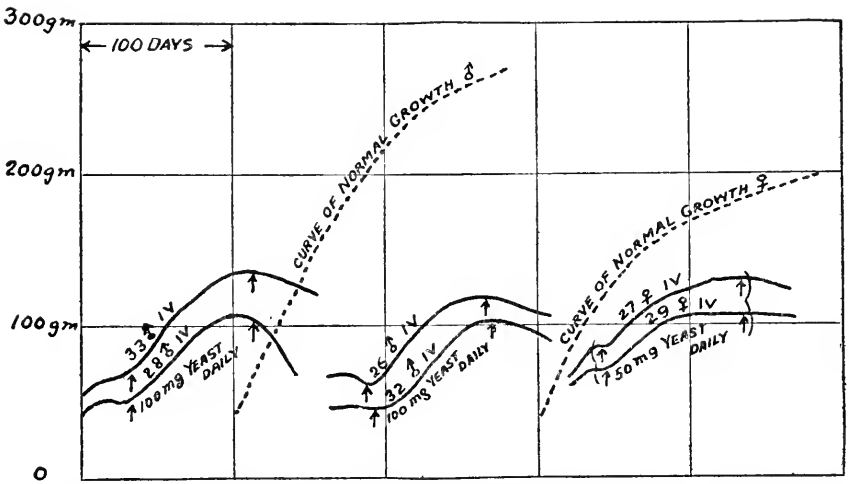

CHART 1.—Showing unsatisfactory growth of albino rats on diets low in raw milk. Addition of yeast resulted in increased growth. (Arrows indicate period of yeast feeding.)

Diet: IV. 100 grams basal, 25 c. c. Agr. Dept. raw milk, 75 c. c. water.

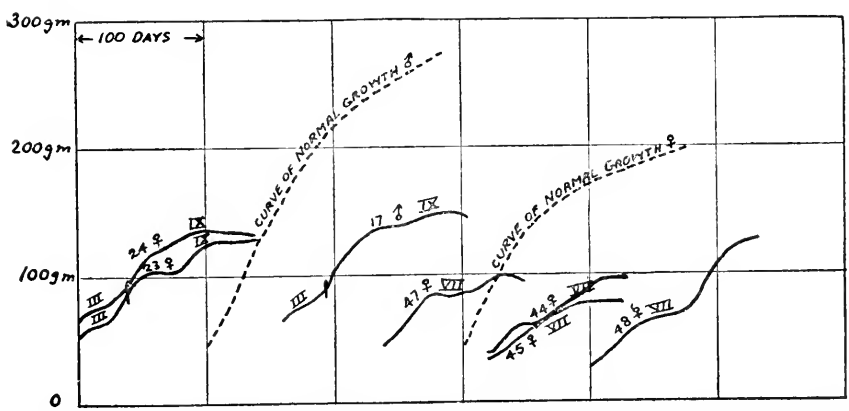

CHART 2.—Showing unsatisfactory growth of albino rats on diets low in milk; no difference between raw and reconstructed milks. Increase of milk in diet caused increased growth (17, 23, 24).

Diets:

III. 100 grams basal, 50 c. c. Agr. Dept. raw milk, 50 c. c. H_2O.
IX. 100 grams basal, 200 c. c. Agr. Dept. raw milk.
VII. 100 grams basal, 50 c. c. reconstructed milk, 50 c. c. H_2O.

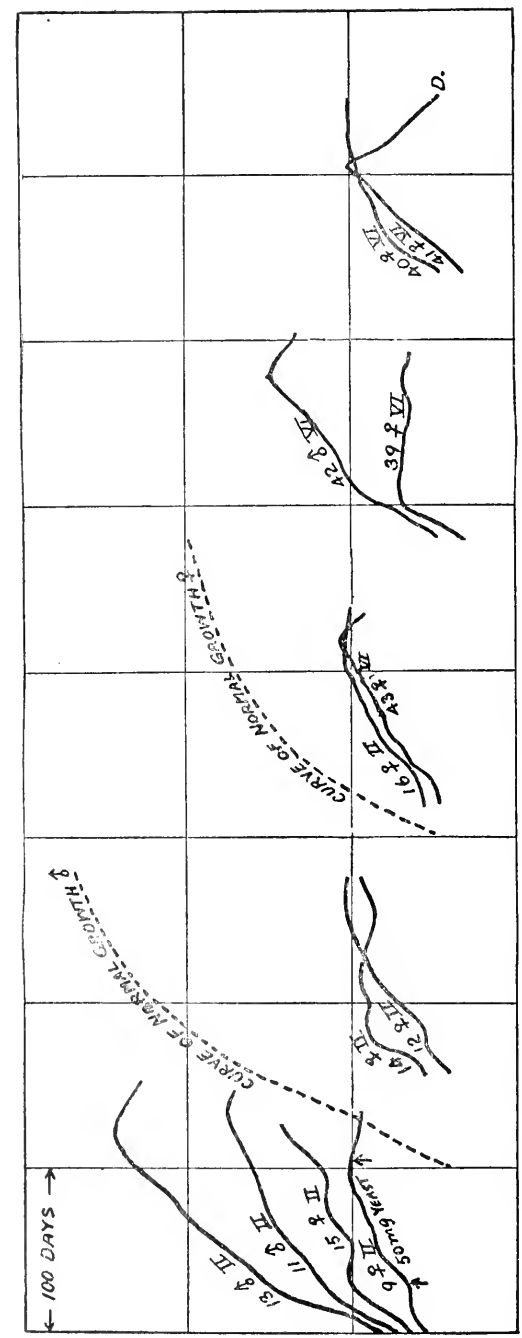

CHART 3.—Showing unsatisfactory growth of albino rats on diets low in milk; raw milk is no better than reconstructed. (Arrows indicate period of yeast feeding in addition.)

Diets:

II. 100 grams basal, 75 c. c. Agr. Dept. raw milk, 25 c. c. H_2O.
VI. 100 grams basal, 75 c. c. reconstructed milk, 25 c. c. H_2O.

Diet XXIII was so mixed as to give in terms of liquid milk the same ratio as three and one-half times as much milk as basal ration. By the use of this diet it was possible to determine whether the subnormal growth observed in rats receiving 3½ parts of liquid milk to 1 part of basal ration was due to an insufficient consumption of solids on account of the excessive water content of such mixtures. The above mixture also contains approximately 24 per cent skim milk powder.

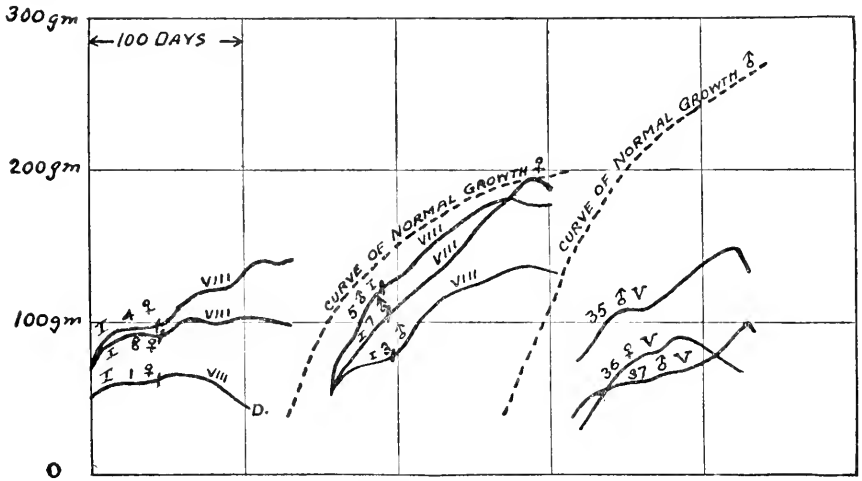

CHART 4.—Showing unsatisfactory growth of albino rats on diets low in milk; raw milk is no better than reconstructed milk.

Diets:

1. 100 grams basal, 100 c. c. Agr. Dept. raw milk.
VIII. 100 grams basal, 150 c. c. Agr. Dept. raw milk.
V. 100 grams basal, 100 c. c. reconstructed milk.

All except one of the animals upon this diet attained full growth. Osborne and Mendel [9] had previously found that 24 per cent was the minimum for whole milk powders in such a mixture to promote growth. These figures of 24 per cent whole milk powder are far in excess of their figures of 16 c. c. daily per animal, going upon the average daily consumption of food by a growing rat.

Charts I–IX give in graphic form the results of the same experiments as shown in the tables. Normal curves are taken from "The Rat," by Henry H. Donaldson, 1915, and are begun at 40 gm. body weight.

SUMMARY.

1. Reconstructed milk made from skim milk powder (spray process), water, and butter fat contains growth-promoting properties for albino rats equal to those of fresh and pasteurized milk; that is to

[9] Loc. cit

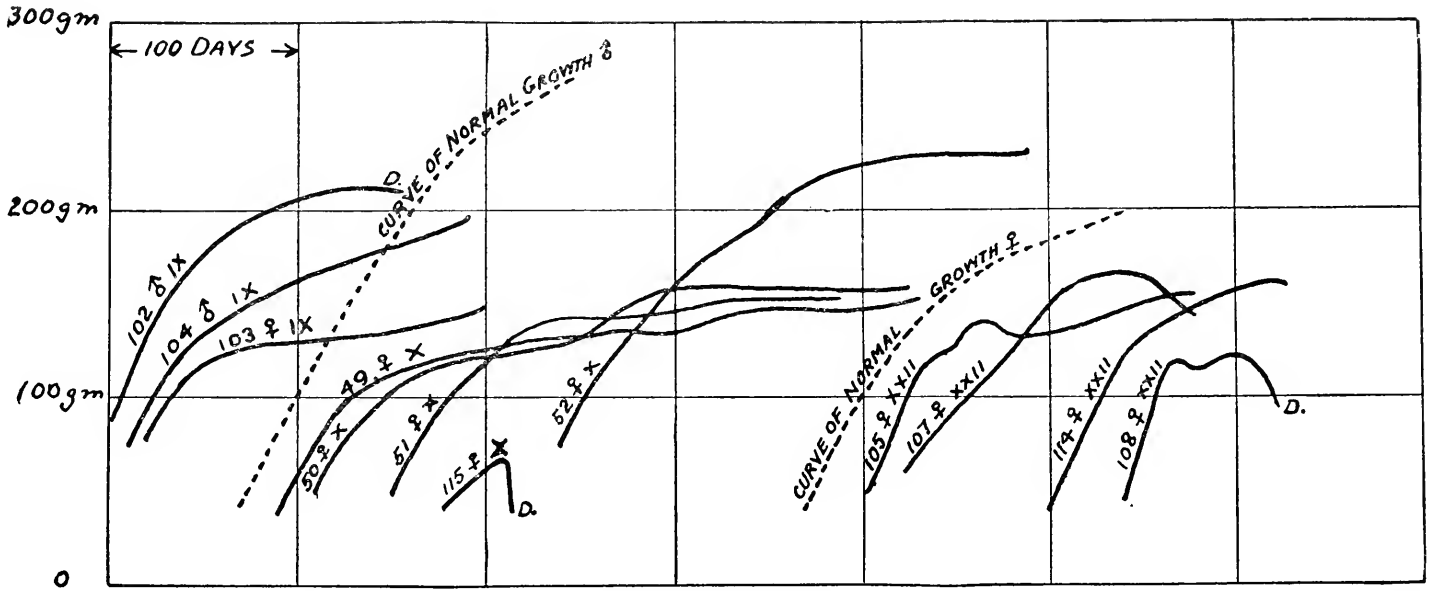

CHART 5.—Showing a growth not quite satisfactory of albino rats on diets composed of 100 grams basal mixture to 200 c. c. milk. There is no difference between raw, pasteurized, and reconstructed milks.

Diets:

IX. 100 grams basal, 200 c. c. Agr. Dept. raw milk.
X. 100 grams basal, 200 c. c. reconstructed milk.
XXII. 100 grams basal, 200 c. c. pasteurized milk.

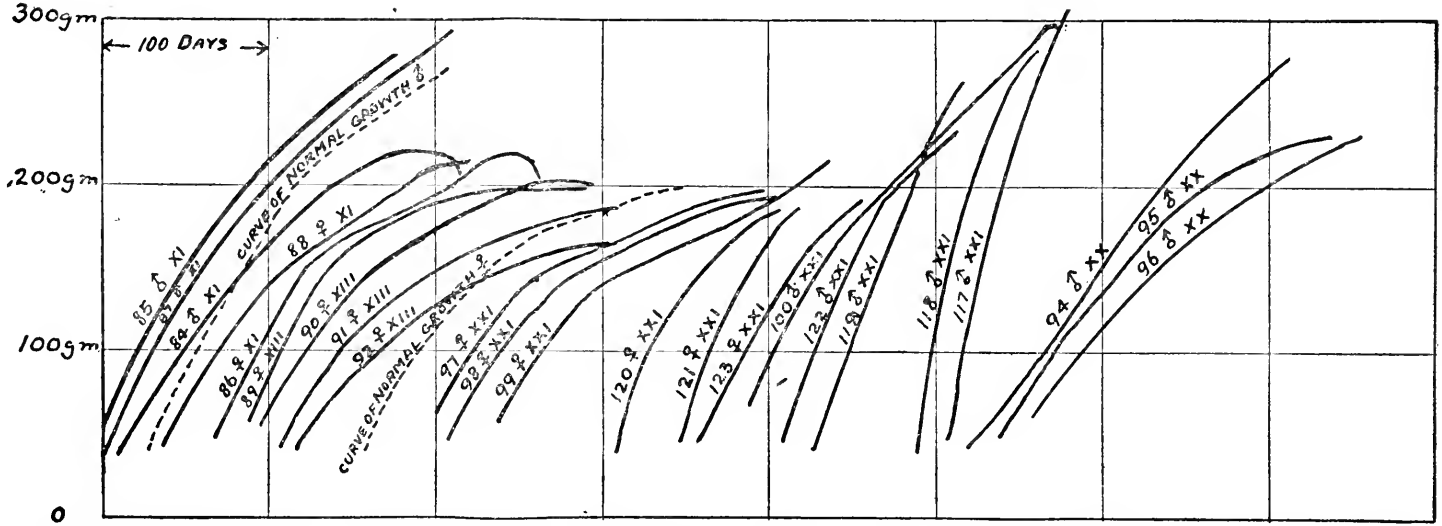

CHART 6.—Showing excellent growth of albino rats on diets composed of 100 grams basal mixture to 250 c. c. of milk. There is no difference between raw, pasteurized, and reconstructed milks.

Diets:

XI. 100 grams basal, 250 c. c. Agr. Dept. raw milk.
XIII. 100 grams basal, 250 c. c. reconstructed milk.
XX. 100 grams basal, 250 c. c. pasteurized milk.
XXI. 100 grams basal, 250 c. c. certified milk.

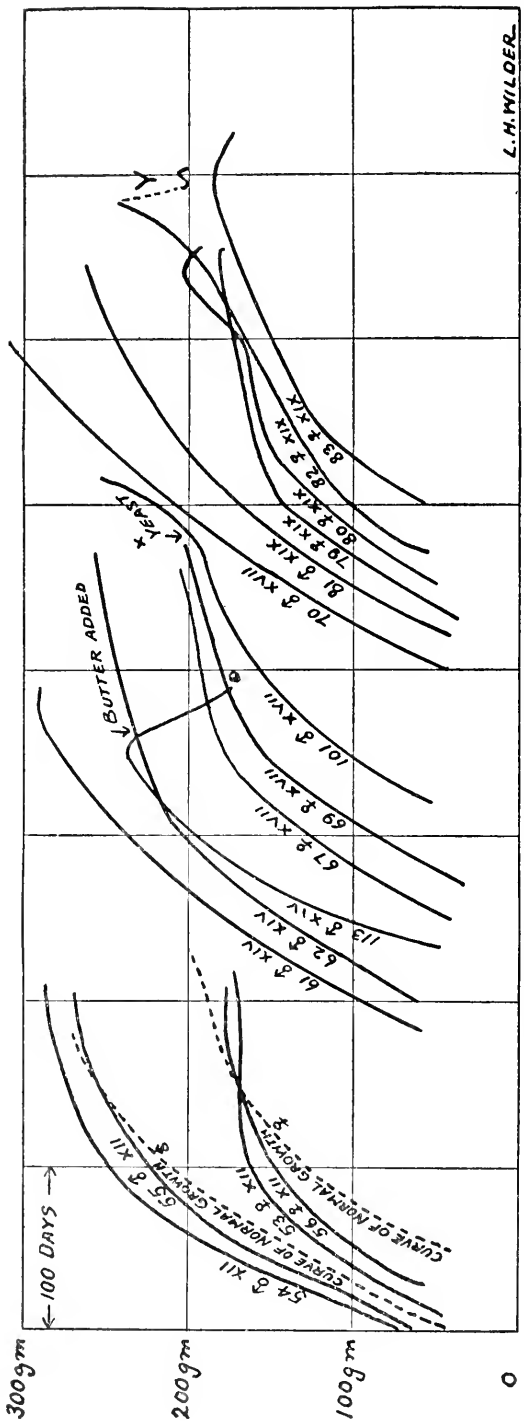

CHART 7.—Showing excellent growth of albino rats on diets high in milk. There is no difference between raw, pasteurized, and reconstructed milks. Addition of butter caused a very slight increase in growth (62). Addition of yeast to diet caused increased growth (101).

Diets.

XII. 100 grams basal, 300 c. c. Agr. Dept. raw milk.
XIV. 100 grams basal, 300 c. c. reconstructed milk.
XVII. 100 grams basal, 300 c. c. pasteurized milk.
XIX. 100 grams basal, 300 c. c. certified milk.
Y. Birth of young.

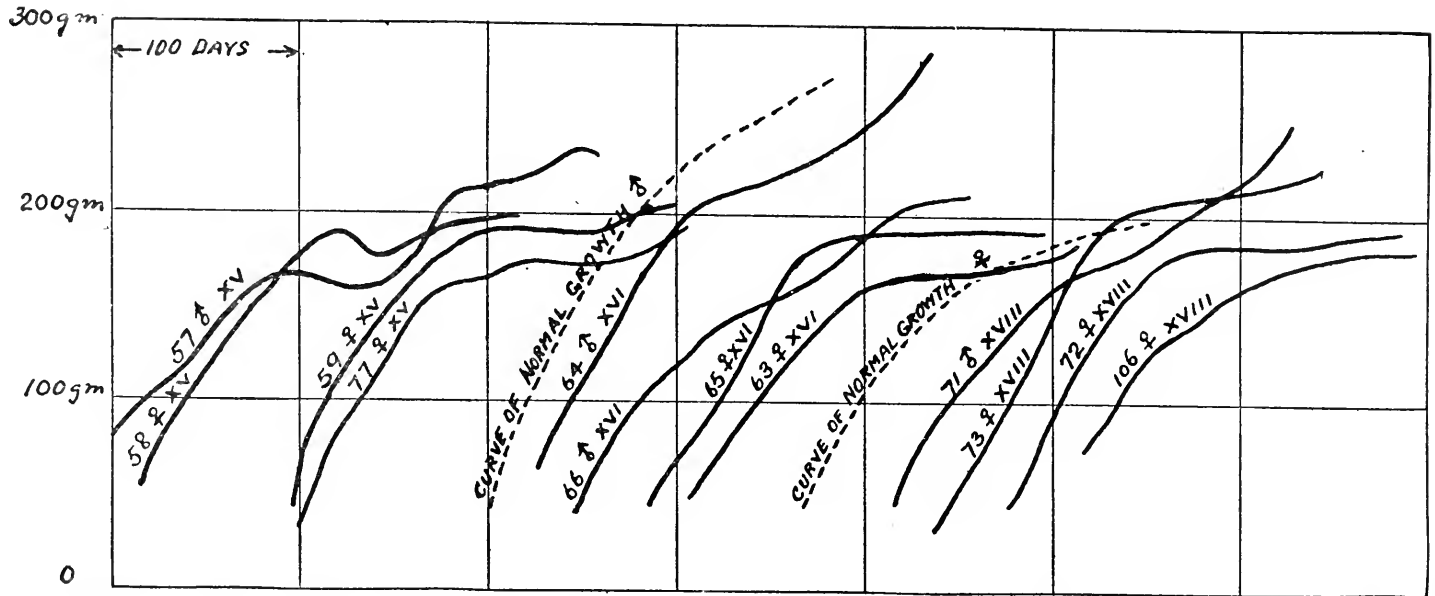

CHART 8.—Showing growth of albino rats on diets composed of 100 grams basal to 350 c. c. of milk. This excessive amount of milk does not give quite as good growth as 250 or 300 c. c. There is no difference between raw, pasteurized, and reconstructed milks.

Diets:

XV. 100 grams basal, 350 c. c. Agr. Dept. raw milk.
XVI. 100 grams basal, 350 c. c. reconstructed milk.
XVIII. 100 grams basal, 350 c. c. pasteurized milk.

say, the process of drying skim milk by the spray process does not injure the water-soluble vitamine.

2. In feeding albino rats a basal mixture of purified foodstuffs plus milk of any kind, it is necessary to give at least 2½ parts of milk to 1 part of the basal mixture in order to promote normal growth. This is confirmatory of Osborne and Mendel, who found that 16 c. c. of fresh milk daily is required by a growing albino rat.

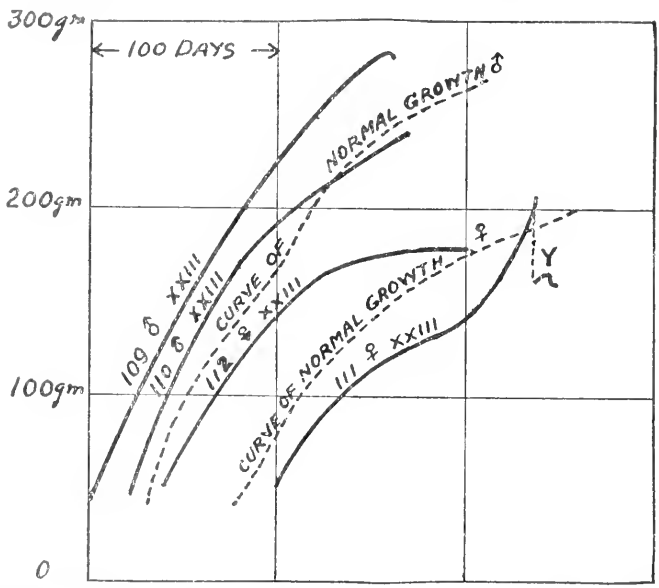

CHART 9.—Showing good growth of albino rats on a diet composed of dry basal mixture and dry skim milk powder. This gave about 24 per cent of milk powder.

Diet: XXIII. 100 grams basal, 31.2 grams spray process skim milk powder, fed dry.
Y, Birth of young.

3. An excessive amount of liquid milk furnished to albino rats gives subnormal growth after a time, because of the large amount of liquid in proportion to the solids in such a diet.

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